



STORMSURGE BARRIER in the New Waterway

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The Maeslant Barriers

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The harbour area of Rotterdam

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The HARINGVLIETSLUICES

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The Netherlands in process

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Rijkswaterstaat

Issues in The Netherlands

- **Policy → implementation: complicated**
- **Involving stakeholders**
- **Room for rivers/ space for water**
- **Financing sustainable operation & maintenance**
- **Role of various public sector levels**
- **Innovative technical solutions**
- **Cost-effective erosion control measures**
- **Public awareness is too low**

Some data in The Netherlands

- **River Rhine:**
 - average 2200 m³/s;
 - top 16,000 m³/s (1/1,250 py)
- **River Meuse:**
 - average 320 m³/s;
 - top 3,800 m³/s (1/1,250 py)
- **Hook of Holland:**
 - average high tide 1.10 m + NAP
 - design value 5,00 m + NAP (1/10,000 py)

Intermezzo: River delta in Bangladesh

- Dry season between 10,000 and 20,000 m³/s
- Monsoon between 80,000 and 150,000 m³/s
- Velocities more then 3.5 m/s = up to 13 km/h

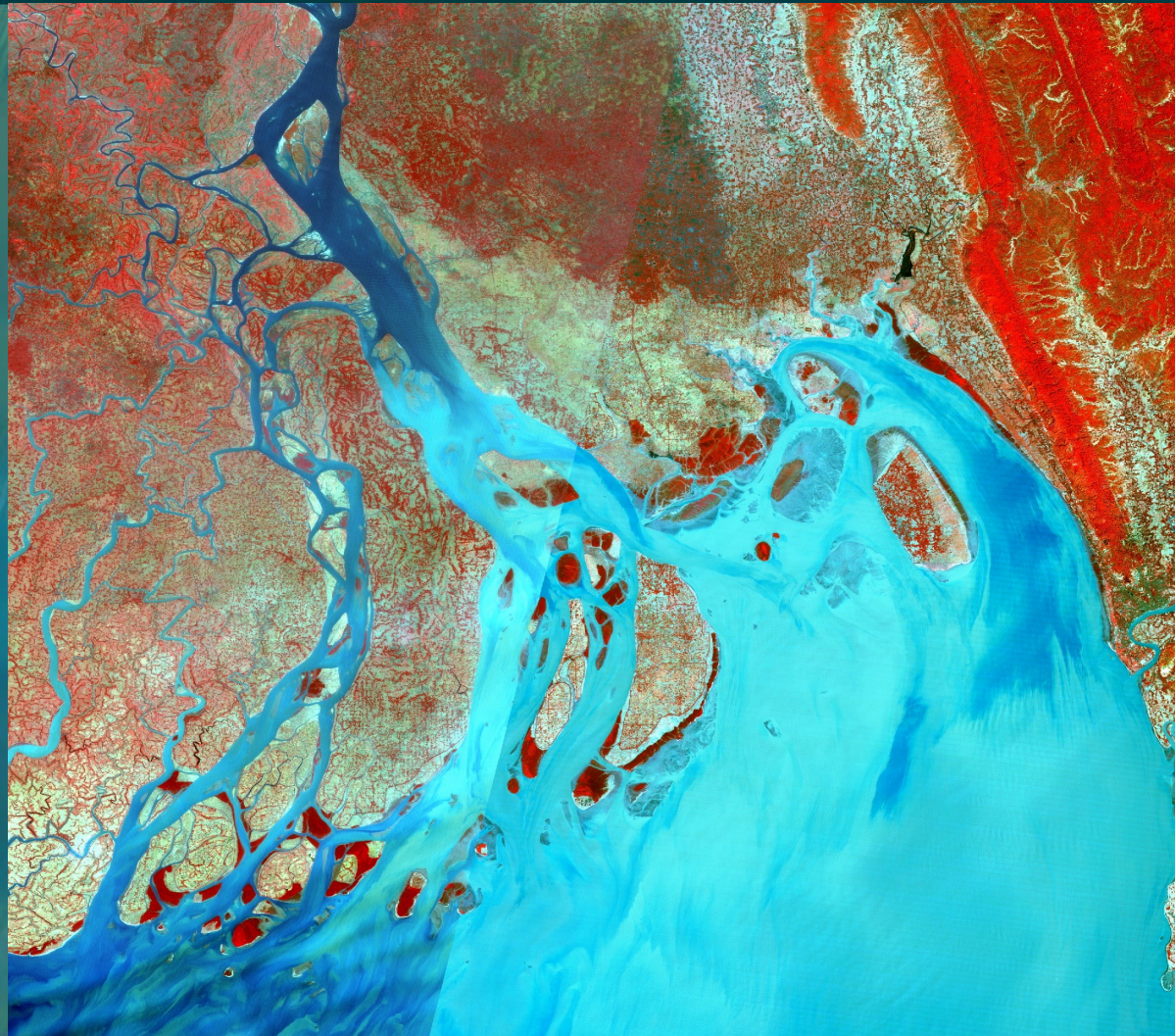
Changes of land masses:

- 1776-1996: 10 km²/ y
- 1973-2000: 51 km²/ y accretion
32 km²/ y erosion
net change 19 km²/ y
- Erosion dominant in years with high floods
88/ 98
- Accretion dominant in years with low floods

Satellite image Meghna estuary

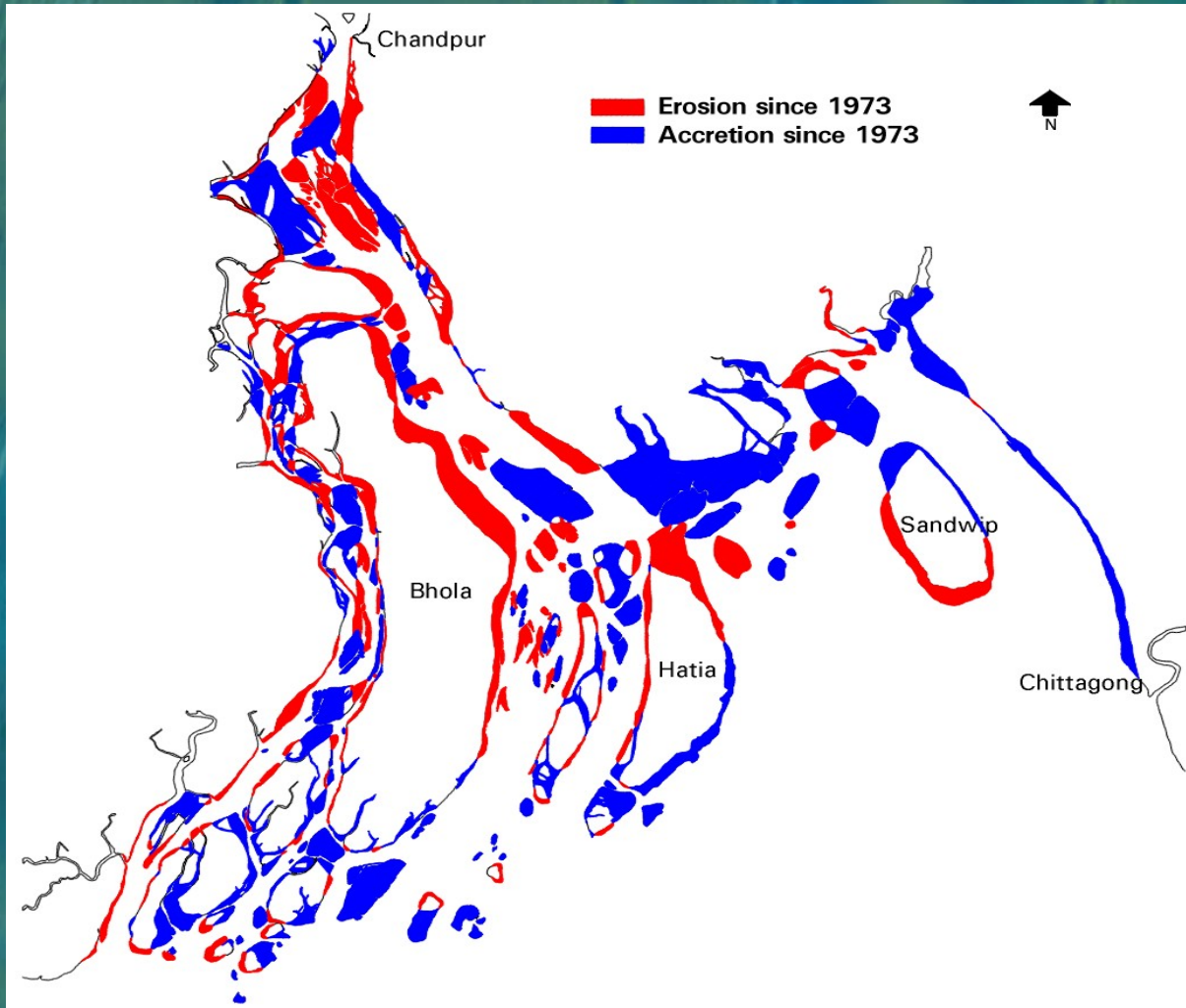
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Erosion & Accretion since 1973

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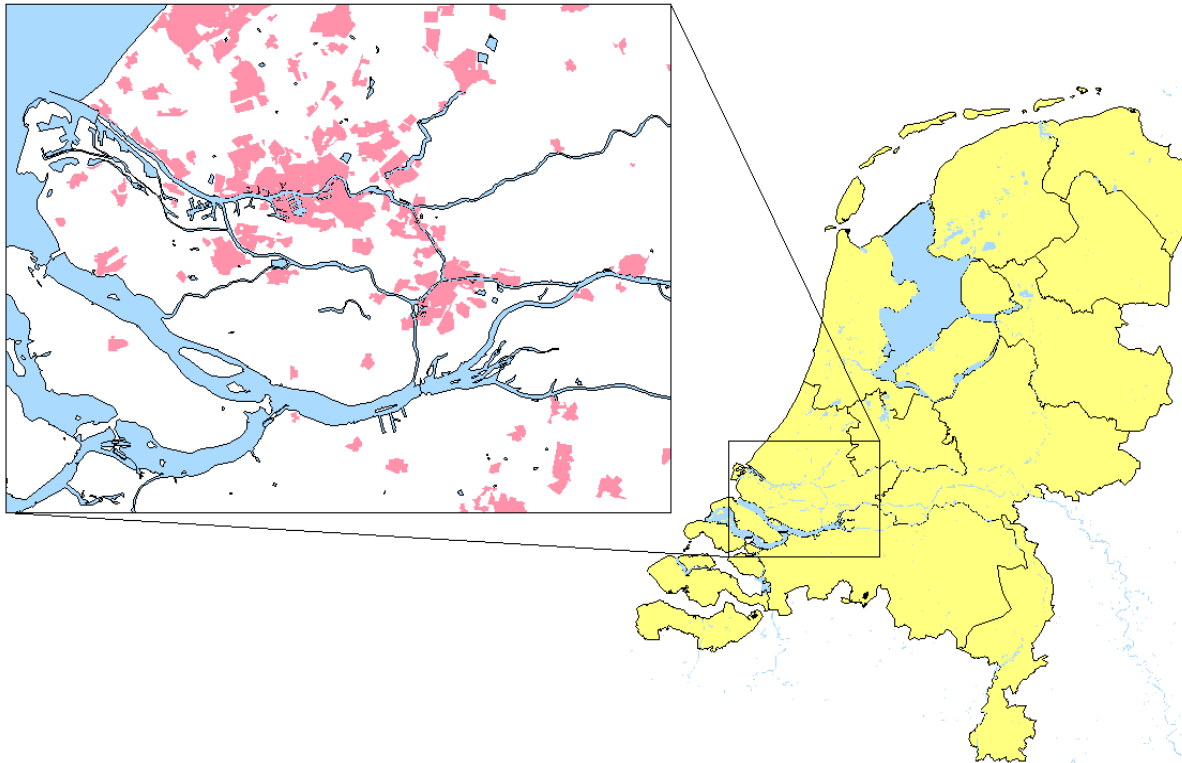


Issues in Bangladesh

- **Decision support methodology**
- **Socio-political commitment**
- **Safety standards**
- **Sediment management**
- **Sustainable financing mechanisms**
- **Innovative technical solutions**
- **Specific: erosion control**

The area: populated/ industrialised

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Safety standards

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Boundary conditions

- Discharges Rhine & Meuse → dependent
- North sea storm surge → independent from river discharges. Other weather system
- NW dominant
- Wind field on delta area
- External & internal wave action
- Storm surge warning → acc 2,5 dm; now 1.5 dm
- Closing 1/10 yr and 1/5 year after 50 years

Combination of hazards

- Tidal movement
- Storm surges with duration, force, direction
- Seiches in harbour area
- Discharges river Rhine
- Discharges river Meuse
- Wind field on water system & internal set-up
- Wave attack s and wave fields due to wind field

Other barriers

- **Easternscheldt**
 - Many gates → always reduction if some fail failure
 - Dike system behind → 1/500 in open situation
 - Probabilistic design
- **Haringvlietsluices**
 - Many gates
 - Double
 - Deterministic design
 - Since 1970 → 500 times per year → 15,000 times

Maeslant Barrier

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- **1 gate**
- **Exceptional construction to operate**
- **Discharges & storm surges to deal with**
- **Complicated operating system**
- **Discharging only by lifting the whole barrier**
- **Failure probabilities of all parts are crucial**

Storm surge barriers (4 altogether) to operate leads to the introduction of more failure possibilities. Vulnerability increases

Failure probabilities

Reliability targets:

- Probability of not closing: $C = 10^{-3}/\text{demand}$
- Barrier failure: $P_{\text{failure}} = 10^{-6}/\text{year}$
- (Accuracy predicted water levels: $\sigma = 0.25\text{m}$)

Extra target for not opening:

- Shipping interest
- Prevent barrier not available in next storm (negative head failure)

Probability of not opening $P_{\text{open}} = 10^{-4}/\text{demand}$

Meeting reliability targets in design:

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Barrier failure (P_{failure}):

Structural reliability → Probabilistic calculation

System reliability → Technical & process analysis

Not-closing (C) :

Barrier not available OR closure system fails

- Human failure
- Technical failure

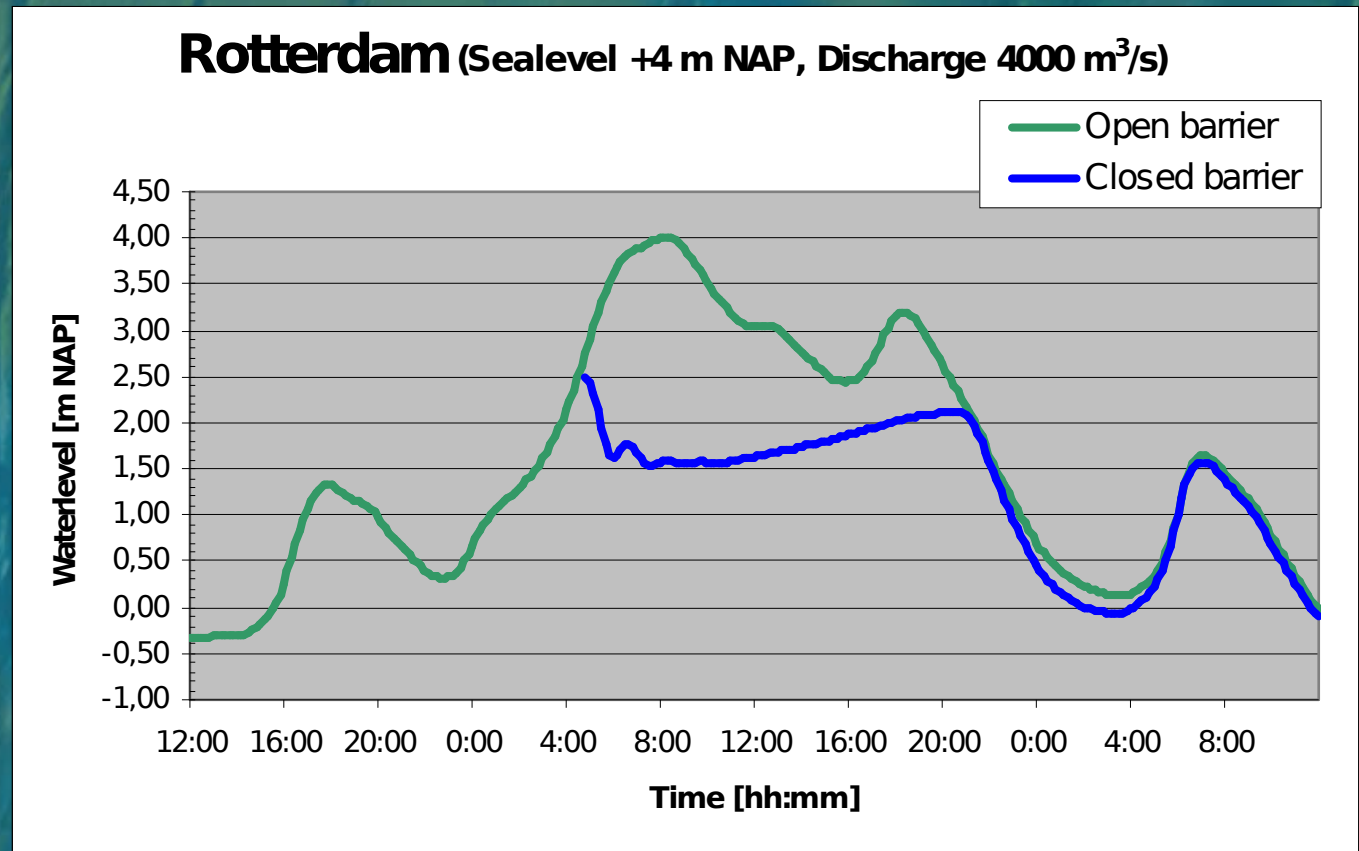
Not-opening: same

All reliability targets could be met

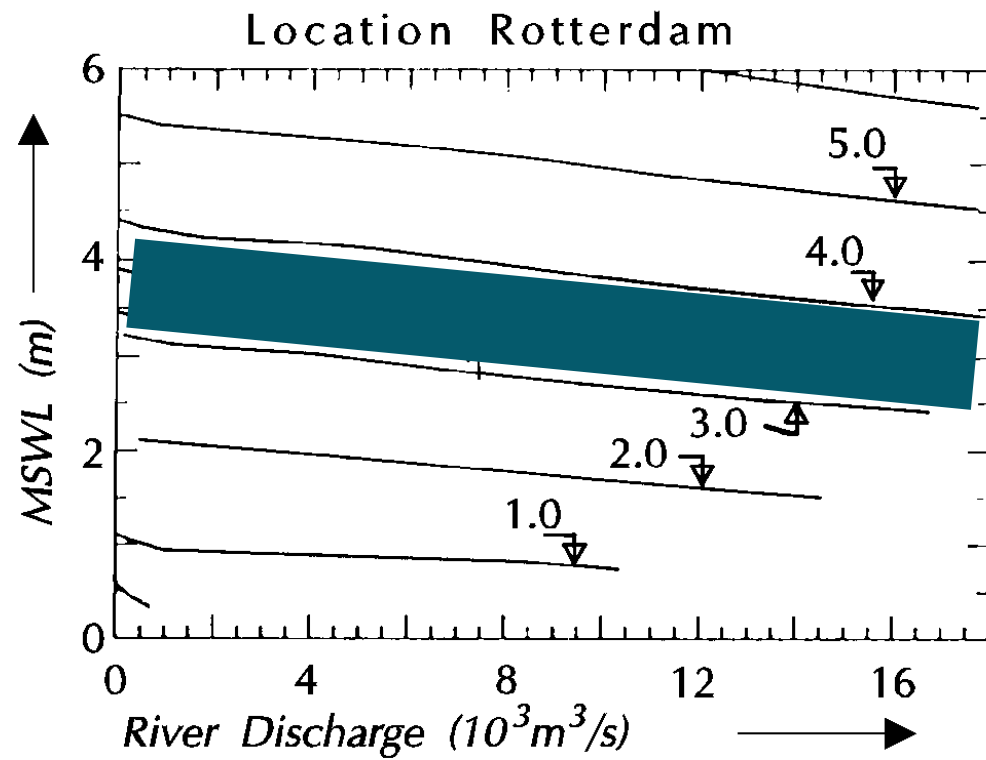
Storm surge with and without barriers

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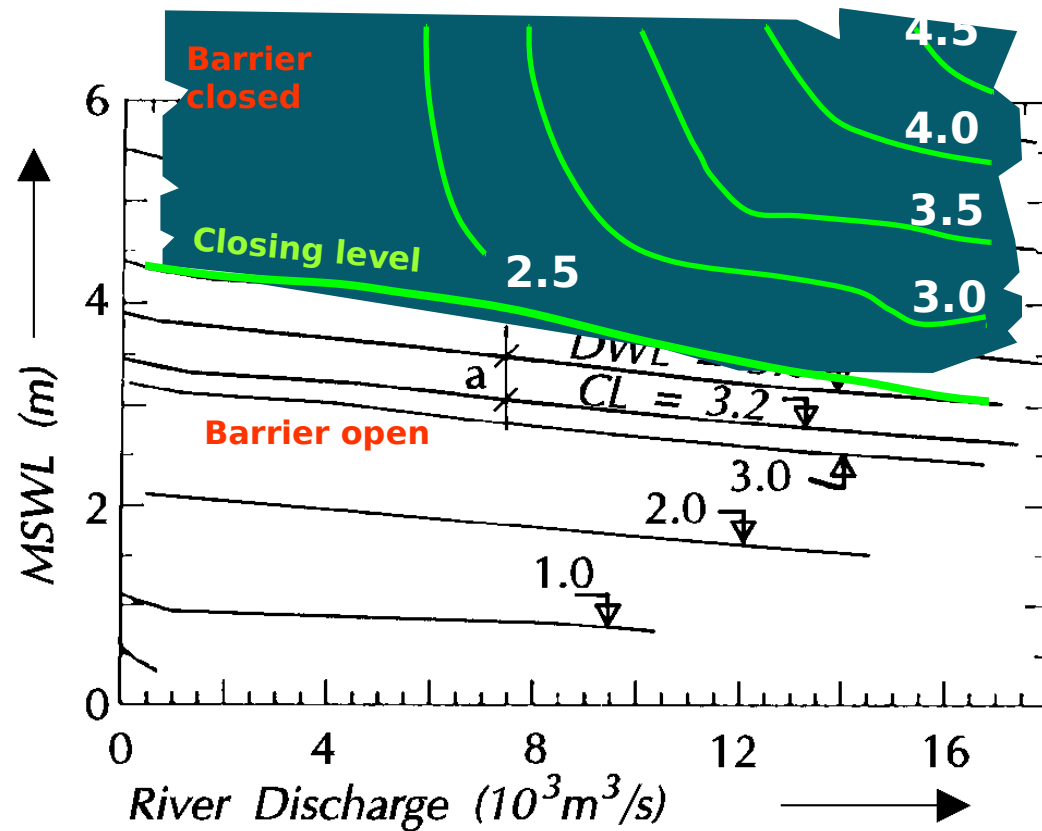


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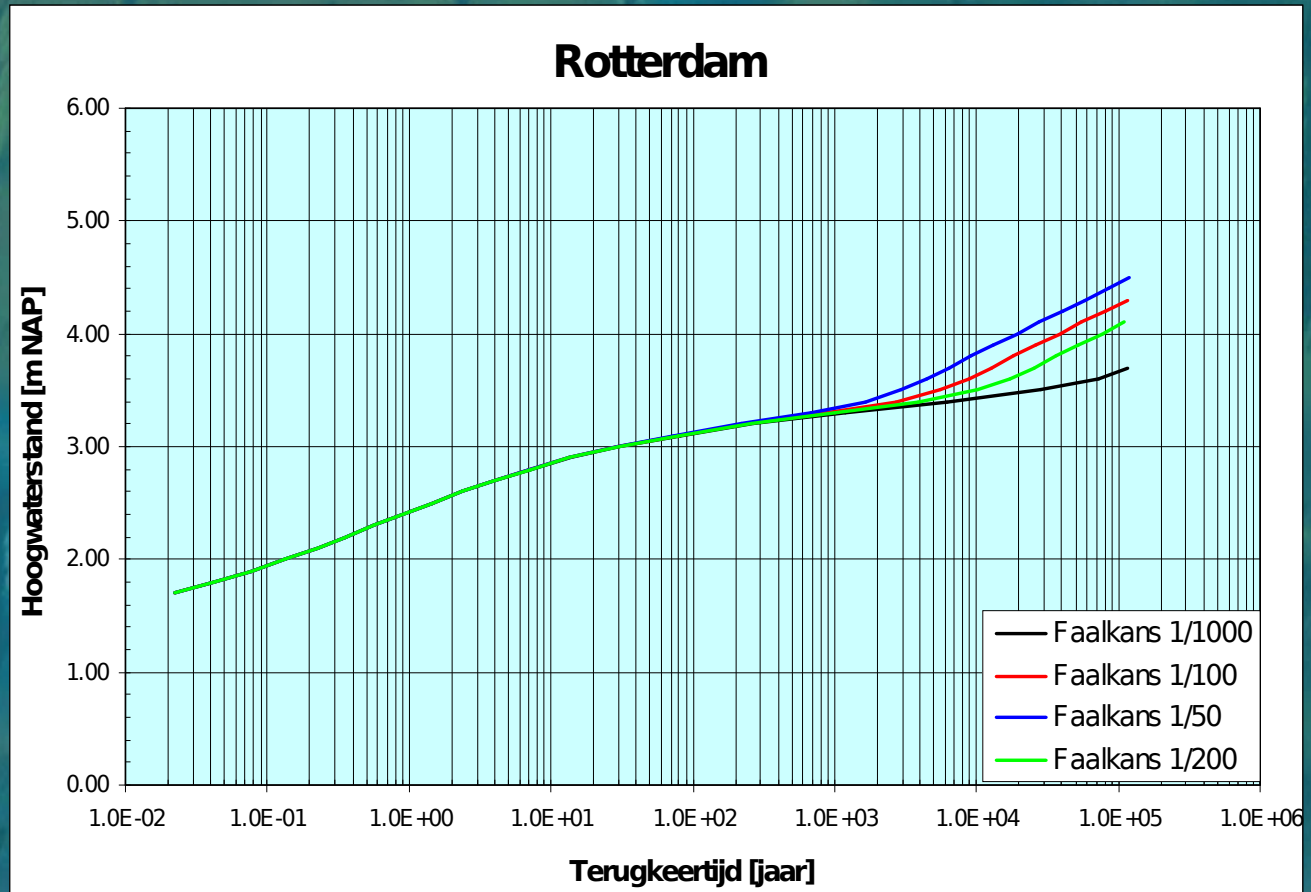
Hydraulic system

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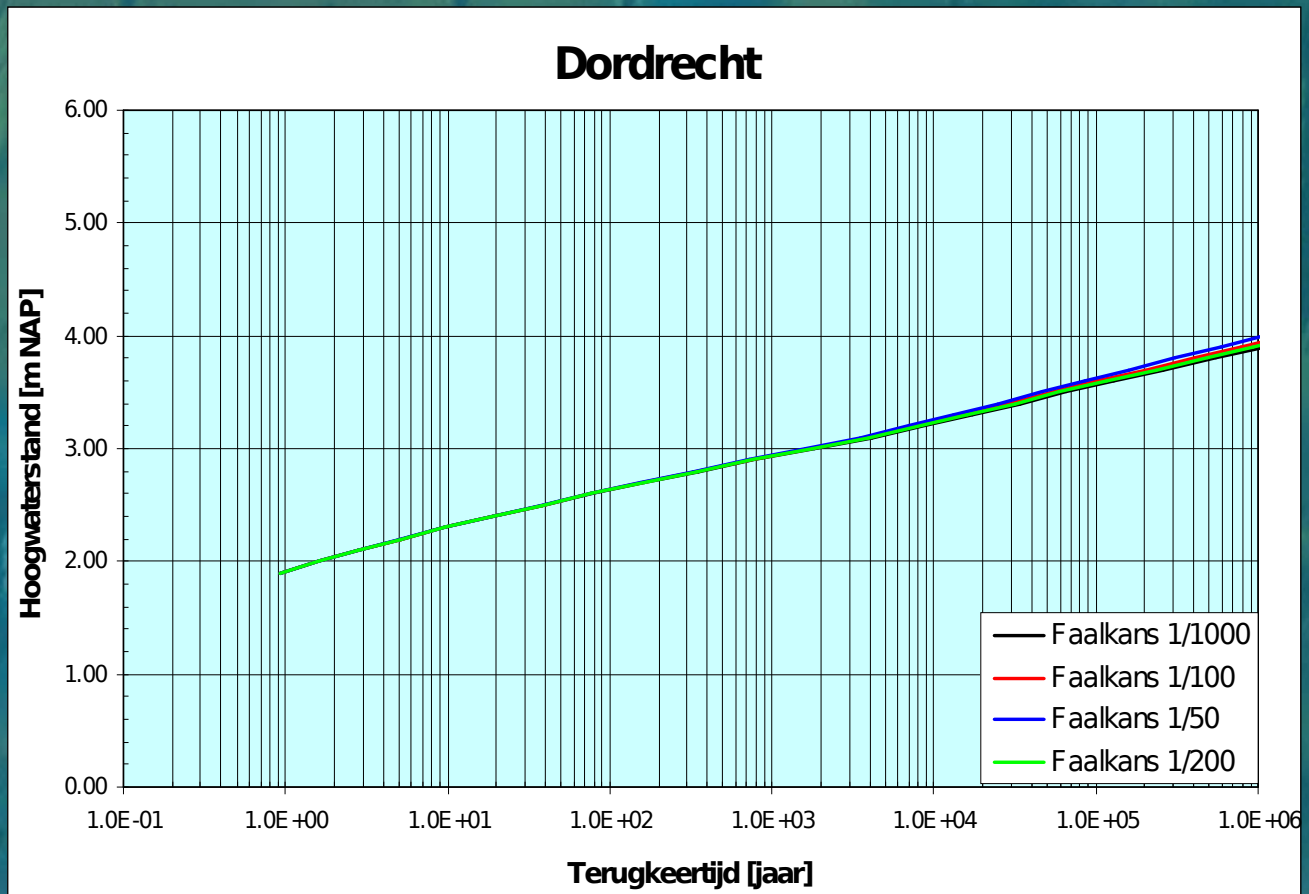
Frequency-lines with various failure probabilities: Rotterdam

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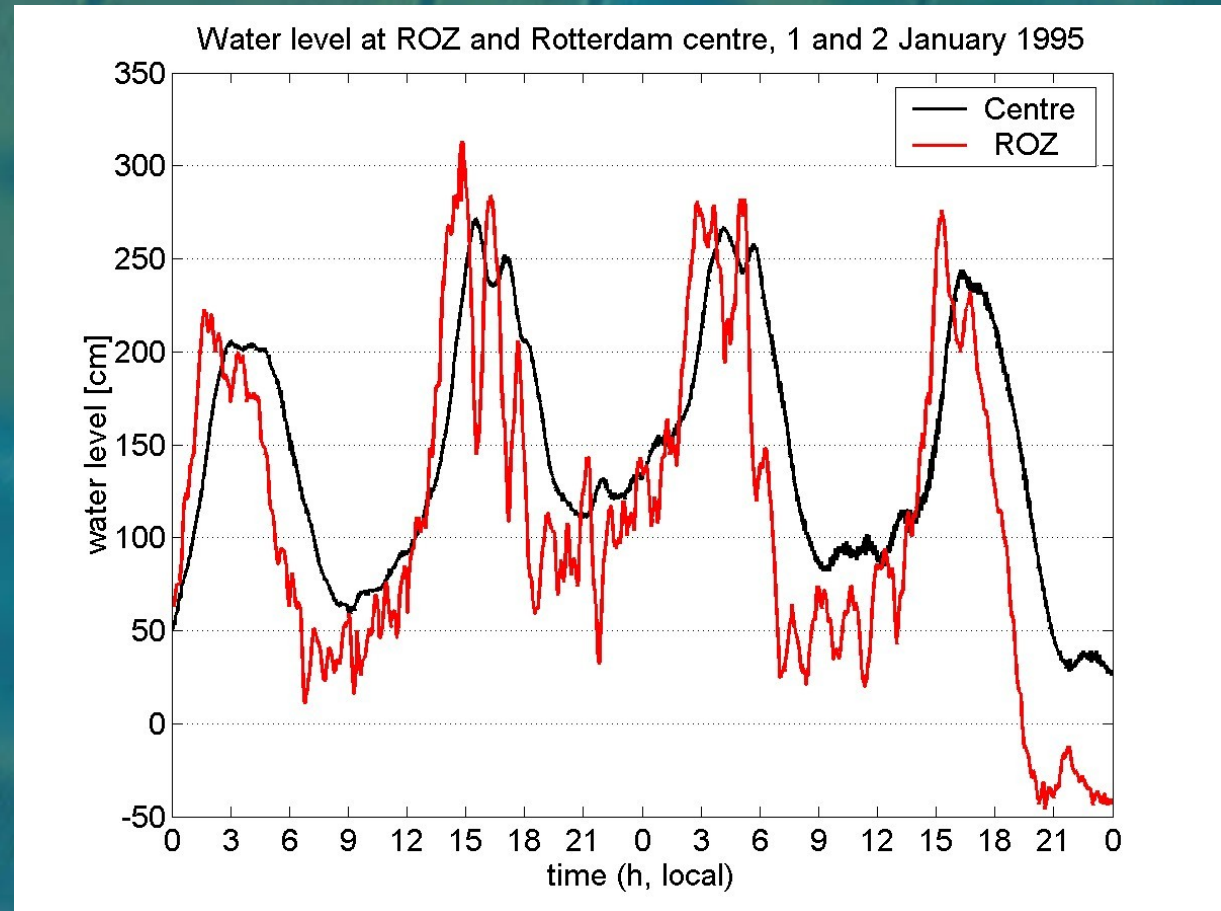
Frequency-lines with various failure probabilities: Dordrecht

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Design problems: Seiches

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Design phase:

Little knowledge about generation seiches
Focus on positive head and max. water levels
Reduced seiche contribution 0.5m (damping because quays are flooded)

Construction phase:

For closing and opening conditions Seiche more extreme (at lower water levels no quays flooded)

Statistical analysis (incl. uncertainty)

→ Seiche amplitude at barrier 1.8m!! (10⁻⁷/yr)

Special design topics: Flow induced vibration

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- Pre-design had sluices (950 m²) to reduce hydraulic head during closure and in the closed situation
- Sluices were removed in D&C contract (cost)
- Model testing showed large dynamic behaviour of main gates (> 3 m amplitude)
 - Positive head: 60 sec.
 - Negative head: 30 sec.
- Final design adapted to prevent dynamic behaviour (1 year delay)

Since 1997 maintenance and yearly test closures showed:

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- **Deficiencies in the operating system (software reliability)**
- **Organisational issues (maintenance crew, procedures)**
- **Hardware problems (e.g. valves ballast tanks)**
- **New insights on software reliability and dependant failure**

Preliminary Risk analysis (2003) showed:

- **Probability of failure too high for closing & opening procedure**

Efforts to guarantee safety

Increase Actual safety level:

- Recovery actions by men (backup)
- Redefine Barrier operation
- Corrective measures in system and hardware
- Testing under extreme conditions
- Probabilistic maintenance
- Long term investing in skilled staff
- Staff who knows in detail the chain of:
 - Background, boundary conditions, maintenance, management, interventions, implementation, spare parts, etc.

Changing boundary conditions

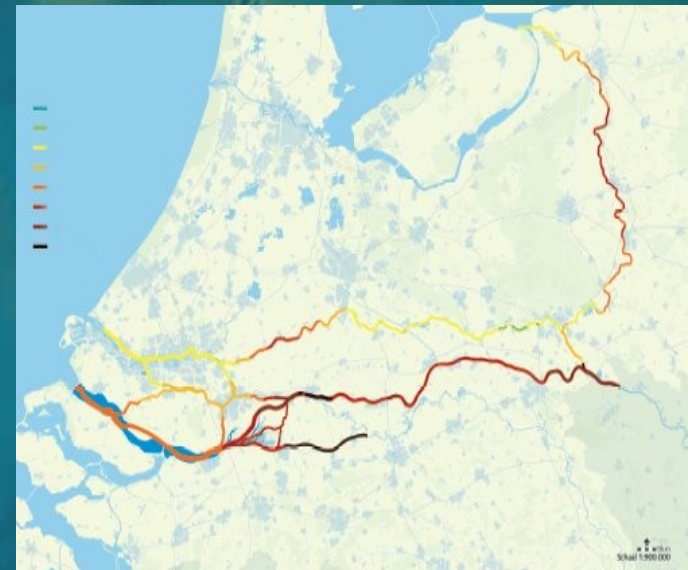
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- **New climate change scenario's**
 - Frequencies top-discharges
 - Changing storm surge patterns
- **Storm surge warning accuracy**
- **Flooding freq of areas outside dike system**
- **Improving technologies, modeling, etc**
- **Vulnerability area behind barrier**

Call for sustainable safety margins in design of the barriers and of the dikes behind.

Concerns

- **Feeling of safety only briefly restored, alas!**
- **Studies and practice show new concerns**
 - sinking land, 13 ft in last 1000 years
 - rising sea level,
 - increasing peak river flows; flooding barely avoided in 1993,1995 (250.000 people evacuated)
- **Dike safety standards are out of date: potential damage 10 times greater than when established**

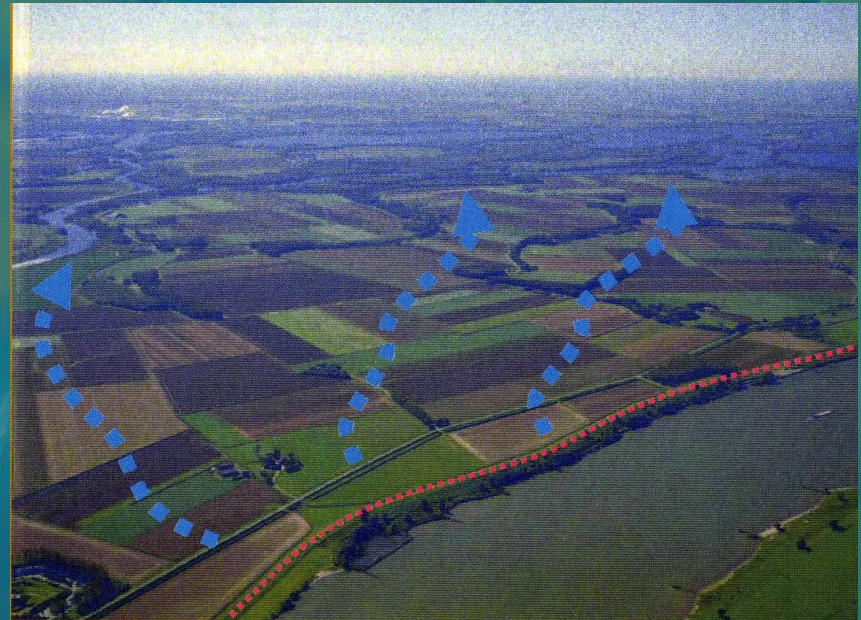


New action plans: rivers

“Room for rivers”, with budget of € 2.5 billion

- Water storage basins for peak flow of rivers
- Creation of secondary water channels to bypass urban area
- Widening and deepening rivers
- Giving thousands of hectares of farmland back to the rivers aiming at a faster discharge of water to the sea

Note: This does not solve the dangers from the sea. The barriers are still needed.



Depoldering Noordwaard

Considerations

- **No single purpose construction. The use can change over time which calls for flexibility**
- **Sustainable: enable future generations to make use of the system in their own way.**
- **Design should be strong. Don't design to critical**
- **Safety margins needed to cope with changing boundary conditions, scientific insights, ...**
- **Call for non-structural solution**
- **Call for innovative designs**
- **Costs of operation & maintenance are always higher when design is too well balanced**

Conclusions

- **With the Maeslant barrier costly and complicated dike strengthening is avoided; natural, cultural, historical values are preserved in combination with a (almost) free harbour entrance.**
- **To guarantee safety against flooding the reliability targets need constant attention**
- **Effective solutions were found for specific design problems although at extra cost and time loss**

Thank you

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